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Please add the following claim.

15. In combination:

a) a steam generator,

b) and means including catalyst extending in a substantially helical path about the steam generator, and in heat transfer relation with the generator,

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c) said catalyst adapted to receive gases which flow along said path and react in the presence of the catalyst to produce exothermic heat that is transferred laterally of said path to the generator.

REMARKS

Extensive changes to overcome '112 objections, have been made in claims 1-12.

As now defined in claim 1, the catalyst bed extends helically, there being flow guide surfaces extending helically adjacent the catalyst to direct gases to flow helically through the bed. This increases the velocity of the gases within the catalyst bed for a given space velocity in enhancing the rate of

heat transfer to an from the bed. The helical structure also serves as an extended heat transfer surface to enhance the rate of heat transfer to and from the steam generator. In this regard, in order to conduct a reaction in a low-temperature shift reactor, a specific volume of catalyst is required to complete the reaction at a given temperature and gas flow rate. Also, because the reaction is exothermic, a specific amount of heat must be removed from the catalyst bed for a given gas flow rate to maintain the reaction temperatures in desirable range. If the temperature is allowed to rise too high, the reaction extent will be limited by equilibrium. The helical flow path of the catalyst decouples the dependency between heat transfer rate, space velocity and catalyst bed aspect ratio. This makes possible the achievement of the required heat transfer rate in combination with the required catalyst volume to conduct the exothermic low-temperature shift reaction for certain practical ranges of gas flow rates and heat removal requirements. These considerations are not taught by the cited art. See the following:

On page 6 of the Action, the Examiner cites Collins et al, who discloses a helical coil (i.e. pipes

468, 470 arranged in helical coils, column 9, lines 35-54, Figs. 3, 7) adjacent the inner and outer walls to conduct and inherently increase the velocity of process gases. These pipes convey natural gas and air respectively and do not contain catalyst. These pipes 468 and 470 are contained in the annular passage between the shroud 350 and the reforming chamber 422.

This citation refers to natural gas and air streams conveyed in empty pipes, rather than synthesis gas conveyed in a low-temperature shift catalyst bed. This citation does not refer to a low-temperature shift reactor, nor does it convey the principals of achieving high velocity in a low-temperature shift catalyst bed that is in contact with a heat transfer surface (steam generator) by virtue of the helical gas flow path in catalyst bed due to the innovative structure disclosed by applicants' invention. No helical catalyst bed is suggested.

On page 9 of the Action, the Examiner cites Sederquist et al who discloses a helical coil (i.e. plurality of cooling coils 40, Fig. 1) adjacent the inner and outer walls to conduct and inherently increase the velocity of process gases as they flow through the catalyst bed 30. This citation refers to

helical coils formed from pipes containing a cooling fluid that are imbedded inside a catalyst bed. The citation does not refer to a helical catalyst structure, as claimed herein.

Claims 11 and 12 refer to a low-temperature shift catalyst which is helical, and transfers heat to a steam generator, which also simultaneously receives heat from other sources such as through heat transfer conduits conveying hot combustion products. No art teaches or suggests this combination.

Added claim 15 defines the helical catalyst extending in a <u>spiral path about</u> a steam generator. The cited references do not suggest this.

Allowance is respectfully urged.

Respectfully submitted,

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Docket 12,150

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CLEAN VERSION OF CLAIMS 1-12.

1. (first amendment) A thermally-integrated water-gas shift reactor for converting reformate gases including carbon monoxide in the presence of steam to form carbon dioxide and water comprising, in combination,

a) a waste-heat recovery steam generator for the recovery of exothermic reaction heat to generate steam,

b) an outer region extending at least part way about said waste-heat recovery steam generator,

c) a catalyst bed located within said outer region, and through which reformate gases flow, said bed extending helically, there being flow guide surfaces extending helically adjacent the catalyst to direct gases to flow helically through the bed,

d) the outer region being in heat transfer communication with the steam generator to maintain the catalyst bed within a predetermined temperature range for operation of a water-gas shift reaction producing said exothermic reactor heat.

2. (first amendment) The combination of claim 1 wherein the waste heat steam generator operates at temperatures in one of the following ranges: 360°F to 450°F, and of 385°F to 400°F, that is optimum for conducting the water-gas shift reaction.

3. (first amendment) The combination of claim 1 wherein said bed includes a Cu/Zn catalyst which is contained in space defined by said outer region, and there being an inner wall adjacent said space and that is in thermal contact with a boiling water fluid in said generator.

4. (first amendment) The combination of claim 3 wherein the boiling water fluid is located proximate the bed to heat the bed during start-up.

5. (first amendment) The combination of claim 3 wherein the catalyst bed extends helically about said waste heat recovery steam generator to transfer heat to the boiling water fluid.

6. (first amendment) The combination of claim 1 including heat transfer fins projecting in said bed to enhance the rate of heat transfer to and from the catalyst bed.

7. (first amendment) The combination of claim 1 including inner and outer walls for defining annular space, and a helical coil at said space to conduct and increase the velocity of the gases as they flow helically through the catalyst bed and to enhance the rate of heat transfer to and from the catalyst bed.

8. (first amendment) The combination of claim 1 wherein the catalyst bed is sufficiently close to said generator to be maintained in one of the following ranges: between 370°F and 550°F, and between 400°F and 450°F.

9. (first amendment) The combination of claim 3 including outside and inside walls defined by said space, and wherein the space is between 1 and 2 inches wide to minimize temperature differentials between the outside and inside walls.

10. (first amendment) The combination of claim 3 wherein the bed has helical length characterized in that the gases have hourly space velocity in the range of 500hr-1 to 2000hr-1.

11. (first amendment) The combination of claim 1 wherein the waste heat stem generator contains one or more heat transfer conduits that transfer heat from combustion products to a boiling water fluid for the purpose of generating steam.

12. (first amendment) The combination of claim 1 wherein the steam generator includes an upright vessel, said outer region having an upper level inlet flowing reformate gases into the catalyst bed, the reformate gases including carbon monoxide, and said region having a lower level outlet, a heat transfer conduit or conduits extending within said vessel and immersed within boiling water contained in said vessel inwardly of said catalyst bed, said conduit or conduits operable for transfer of heat to the boiling water, for generating steam exiting from said vessel.

CLEAN VERSION OF SPECIFICATION AT PAGE 10, line 9 (now line 10) and line 17.

commonly referred to in the industry as a steam reformer. Fuel 5 and air 6 are combusted in the chamber 4 to heat the reactant mixture so as to produce a hydrogen-rich stream 7 containing carbon monoxide concentrations typically ranging from 5% to 15%.

Combustion products 8 from the combustion chamber pass through a flue gas heat exchange coil 9 that is contained within a waste heat stem generator 10, wherein the combustion products are cooled and steam 11 is generated. The cooled combustion products 13 are further cooled by exchanging heat in a feed water exchanger 14 that produces heated water 15 that is supplied to the waste heat steam generator 10.

The hydrogen-rich stream 7 from the tubular catalytic reactor 3 is cooled in an exchanger 2 to a temperature typically in the range of 400°F-550°F whereupon the cooled stream 18 is introduced into a fixed-bed catalytic reactor 19 shown as surrounding steam generator 10, to effect a water gas shift reaction that converts a portion of the carbon monoxide to hydrogen and carbon dioxide by reaction with steam. The catalyst bed reactor typically contains a supported Cu/Zn catalyst and is commonly known in the industry as a low temperature shift reactor. The walls 20 of the low temperature shift reactor are in thermal communication with boiling water contained in the waste

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MARKED UP VERSION OF SPECIFICATION AT PAGE 10, LINES 9 and 17

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Combustion products 8 from the combustion chamber pass through a flue gas heat exchange coil 9 that is contained within a waste heat stem generator 10, wherein the combustion products are cooled and (stem) STEAM 11 is generated. The cooled combustion products 13 are further cooled by exchanging heat in a feed water exchanger 14 that produces heated water 15 that is supplied to the waste heat steam generator 10.

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